GENERAL SERRELL'S REPORT

ON THE LOCATION OF THE

Hudson Highland Suspension Bridge.

CHIEF ENGINEERS' OFFICE,
Hudson Highland Suspension Bridge,
New York, August 10th, 1868.

To the Executive Committee.

GENTLEMEN:

In compliance with your resolution of the 17th June, directing the Chief Engineer to tabulate the facts at the different proposed crossings, particularly with reference to the approaches, in order that the board may with precision select the very best, I have the honor to submit herewith a tracing of the primary, and secondary triangulations, and other measurements made on the ground, and compiled from surveys previously made, together with such calculations, and other data, as will, I believe, comply with your instructions, and enable you to decide where the best location for the bridge is to be found.

In making these examinations, I have been governed solely by the facts, as they are found on the ground, and I am greatly indebted to the United States Coast Survey office for collateral valuable information furnished.

By the first section of the act incorporating the company, chapter 332 of the laws of 1868, you are authorized "to construct and maintain a permanent Bridge, appurtenances, and avenues of approach thereto for the passage and transportation of passengers, railroad trains, vehicles, cattle, horses, &c., &c. to, and from the east, and west banks of the Hudson River, at some point, or points between Verplanck's Point and Buttermilk Falls on said river."

Verplanck's Point and Buttermilk Falls, are about ten miles apart, and within this whole included space, all the shore lines have been traced, and at every position having the appearance of offering such facilities for crossing the Hudson River by Bridge, as you require, minute measurements have been made.

Very nearly all the crest lines have been run out on both sides of the River, and contours traced to afford minute information of the topography.

In addition to such surveys as seemed necessary to ascertain the best position for the Bridge, considered as an independent structure, measurements have been made, lines run, and cross-sections taken to give you all required information, respecting the proposed avenues of approach, highways leading to the Bridge, and particularly having in mind the great system of railways leading to, and from your work, very accurate information has been obtained by actual survey, showing the grades and alignments of various routes, practicable and impracticable, reaching the different sites of the Bridge, upon which estimates have been made.

Within the limits authorized by law, over which you are allowed to cross the river, the water-way varies in width from less than five hundred yards to over a mile and a quarter.

The location is in the beautiful and grand highlands, classical and historic, far lovelier than any portion of the Rhine, bolder, and more distinct in its character than any part of the valley of the Father of Waters.

Topographically the region may be described as mountainous. At the southwesterly portion of the district stands the "Dunderberg," towering to a height of 1550 feet above the river. This mountain breaks down to the westward near to, and connects with "Bear Hill" to the north of which is "Popolopen" Creek, the head waters of which are not far from the celebrated "Forest of Dean" iron mines.

Northerly of Popolopen, is the "Torn Mountain," which is more or less distinctly defined, as it occupies the Westerly Slope ot the Valley of the Hudson for some six miles, and then is merged into "Crow's Nest," to the rear of the Military Post

of West Point. This range is however broken through by the secondary valley, in which is Buttermilk Falls. South of Popolopen there is a table-land, about one hundred and fifty feet high, triangular in form, about one mile and a half in length, and a mile wide at the northerly end.

The shores of the River at the Dunderburg, are in most places precipitious: and this is their character all the way to the southward from the table-land before described as far as your assigned limits extend.

North of the Popolopen and between the river and the Torn Mountain, there is a plain of nearly the same elevation as that south of the stream and this extends with more or less distinctness to Buttermilk Falls. At the river south of Popolopen, the locality is called Fort Clinton, and north of the creek Fort Montgomery, both of them localities of revolutionary note, and being among the initial points are frequently referred to, in this communication.

A locality, known as Doodletown is situated on the northerly side of the Dunderberg between it and Bear Hill, here the drainage of the country forms a little brook: except Popolopen this is the only considerable stream on the westerly side of the river within our included space.

On the easterly bank of the Hudson, directly opposite Fort Clinton, is a bold promontory known as "St. Anthony's Nose." This is very abrupt at the water-line, and the Hudson River rail-road tunnels the point.

The Mountain is reported from various sources to be from 1228 to 1418 feet in hight. For your purposes, it was not considered necessary to ascertain the altitude. The mountain forming the continuation of the promontory is very well defined, of bold distinct outline, without any very decided passes, *except one very high one*, through which the wagon road from Peekskill to Garrison's passes.

The general direction of the range is north-east, and south-west, and it rises to a crest line of several miles in length, forming an angle with the general direction of the Hudson river of some forty degrees.

The general direction of the Valley of the Hudson is due north and south, although below "St. Antnony's Nose," the tend is to the eastward, say south-east, for some three or four miles, and north of the "Nose," north-easterly some four or five miles.

Directly above the "Nose" the shore of the river is low, and marshy, for some three hundred yards, or more, above this, there is a terrace, and this is some one hundred and forty, to one hundred and sixty feet high; and extends to the water's edge with abrupt precipitous cliffs of rock, nearly all the way to Garrison's Landing which is just above Buttermilk Falls, and on the opposite side of the river.

Above this plain on the river, and opposite Buttermilk Falls, and to the eastward of the plain just described is the hill, known as "Sugar Loaf," one of the most prominent features of the landscape. This is a conical mountain on its east and west section, and serves as a good point of reference.

In the wide part of the river opposite the intersection of the Dunderberg and Bear Hill, and in front of Doodletown is "Grant's or "Ionia Island", containing some 120 acres, and immediately below is "Round Island," containing 10 acres.

South of Buttermilk Falls on the westerly side of the river, there is a rocky promontory separated from the main shore by a salt marsh, the place is known as "Consute," or "Marsh Island."

It is really not an Island at all, being connected with the bluffs of the river side by a passable rocky marsh, covered with sedge.

The high table land south of West Point, and east of the Torn Mountain, extends to Fort Montgomery, but is broken through by a ridge of granite at Cozzens. It contains about 700 acres, south of the northern limits of your location at an elevation of from one hundred and fifty, to one hundred and sixty feet above tide.

The similar plateau below the Popolopen Creek contains about one hundred and thirty acres, exclusive of the Beautiful sheet of water, known as "Highland Lake," which is some half a mile long, and two hundred yards wide, and is at an elevation of about one hundred and forty seven feet above tide.

On the easterly side of the river, south of your northern limits, the plateau contains about three hundred, and twenty-five acres, and this plain extends to the north some miles, at nearly the same elevation that the corresponding Bench has on the opposite side. That is, it varies in hight from one hundred and forty, to one hundred and seventy feet above tide, and is broken through by a small stream, nearly opposite the south end of Consute Island.

To the westward of Round Island, Ionia and Consute respectively, the rocks are joined to the right bank of the river by river deposits, forming marshes, and northerly of St. Anthony's Nose on the left bank, there is a triangular marsh of the same character.

There are also, some small swamps on the margin of the river in the rocky coves, most of which contain from a few hundred square feet to say half an acre.

Southerly from St. Anthony's Nose, on the easterly side of the river, the mountain is parallel to the water-course, and very steep, rocky and abrupt for over a mile. It is then broken into, by a small secondary valley, and again rises to a great elevation, a portion of the distance being almost vertical.

Opposite to Round Island, there is another nose, and from this, the face of the cliff tends to the south-east, leaving the river between which and the mountain, there is an elevated plain, with some hills upon it; the most southerly part is called "Roay Hook."

Peekskill Creek hollow breaks into the north eastward, below the point, and at its confluence, with the Hudson, the valley is half a mile wide, or more.

The stream is tide water for a mile or so, to where the Annsville Creek intersects it; this latter comes from the hills of Putnam County, and has a bed upon a high angle of inclination.

Southerly towards Verplank's Point from Peekskill Creek, and Annsville Stream the country is a very irregular plain, sloping from the Hudson to an elevation of about one hundred and sixty feet high, where it spreads out into a general level, upon which is built the fine village of Peekskill.

There is through this plane a stream affording fine water privileges. Still further to the south, the land is high, and irregular.

The Hudson River at Peekskill is over a mile and a quarter wide, and the landing places are in a deep bend, almost an elbow. The Dunderberg forms the salient of the right bank directly opposite.

Geologically the region should be considered as composed of primitive rocks, although there are some detached limestones in veins and masses.

Quantities of iron exist combined with feldspar and sulphur, and this enters largely into the discussion of suitable anchorage ground: green stone in seams, and some hornblende in masses may be foand scattered.

There are some segregated seams of plumbago in the detached limestones, and these have occasioned much reflection upon the probable effect of the rocks, or their contained alkalies upon the iron, and steel of the Bridge.

The granite of which most of the district consists, varies very much in character. Some is solid, and compact in large blocks, without seams of any kind, blue, or whitish in color; other portions are chloritic and of irregular fracture. Some contain an excess of mica, others large quantities of feldspar. have not seen hornblende, or quartz in excess, except very irregularly.

The very best granite for building exists but the quarries generally have not been opened.

One quarry on the east side about a mile above St. Anthony's Nose, has had some fine stones taken out of it; the quarries are not however very large, at least such seems to be the case from present appearances.

South of Verplanck's Point on the opposite side of the river, there are some very valuable lime quarries, but no stone of this kind suitable for building. There is at this locality and at Roay Hook, very excellent sand for cement mortar and to the west of Consute Island about a mile, very good fine gravel and building sand.

Having thus endeavored, to give you some faint idea of the physical character of the country surrounding and including the region, you are authorized by law to occupy, for a crossing of the mighty Hudson, so far as the topography and geology are concerned, let us before going any further, enquire for a moment into the climate, we have to deal with.

Although in the mountains, and some fifty miles from the sea, the Hudson River is for the greater part of the year quite salt at this place, and is influenced by the tides, and the southerly winds from the Bay of New York, and the Tappan Zee: they are by no means what we usually designate upland breezes. They are, in fact, almost salt air, considered with reference to iron structures.

The thermal range is very great in the Highlands of the Hudson, and equals one hundred and sixty degrees Fahrenheit; at least so very considerable a quantity has to be provided for in all your mechanism for compensating expansions and contractions due to this cause.

Snow falls in great quantities, frequently six or seven feet deep on a level, and in the drifts many times this amount, and the winds are frequent and severe. I have been enabled through the kindness of scientific gentlemen living in the neighborhood, and from observations made during many years past, by order of the government to obtain valuable information on these subjects. The quantity of rain, and snow which falls in a year and also the greatest amount that has accumulated for many years past is recorded; and the direction, velocity, and force of the wind at different places in the vicinity is known.

I have, however, been unable as yet, to collect any considerable amount of reliable information, respecting the electrical, or magnetic phenomena of the region, and but little seems to be known, or at least I have not found it recorded; and many meteorological facts which should be well understood while building such a large and important work as you contemplate, have not been collected, apparently, and there has not been sufficient time since your orders were given, to obtain them by a series of personal investigations.

I think though, you may now rest assured, that sufficient in-

formation has been obtained of the topography, geology, and climate to enable you to form an intelligent opinion, and come to a wise and reliable judgment in determining the location for the Bridge.

So much for these points; let us now consider analytically the geometry of the case.

The line A. A'. is a section at Round Island. It begins on the northerly face of the Dunderberg mountain, at an elevation of one hundred and sixty feet above tide, and crosses to a projection of the southerly face of the prolongation of the range, forming at the River, St. Anthony's Nose, and passes over Round Island, somewhat to the south-ward of the centre of the island.

At an elevation of one hundred and fifty feet high above tide, level grade would strike the natural surface at two points on opposite sides of the river, five thousand three hundred and seventy-two feet (5372) apart.

Round Island is about ninety five feet high, at the highest point above high water and affords facilities for a tower and foundations, but is not wide enough in the direction of the axis to make anchorage upon; and the highest points are not in the axial lines, because if the centre of the Bridge was made to coincide with the summit, the axis would be thrown too far down the hill-side of the Dunderberg, or too high on the edge of the mountain on the east side of the river.

As before stated, westwardly of Round Island there is a marsh, connecting it with the right bank of the river. This marsh is deep, and soft; but the extent of the mud has not been ascertained by us. From various indications, my assistants report their belief that it is from forty to fifty feet deep.

The marsh is 1937 feet wide between the rocks on either side.

If two spans of a Suspension Bridge or any analagous system were built at this crossing, they must be, if equal in extent, each two thousand feet in the clear. It is possible however that spans of unequal length might be made at this place, one of which would be of less extent.

In any case, very heavy masonry in the approaches and abutments, would be required.

The strains upon the main cables, at the above named section have been calculated, and you will find their ratio tabulated with those obtained at the other crossings.

A design has been made, and some estimates worked up for one span over the water way of the river, and masonry arches over the marsh, and the easterly approach ; and as regards its architectural effect may be very acceptable ; but before any decision could be properly made for, or against it, many other localities should be examined, and you may find it suffers by comparison with them.

You will find in the table of ratios an approximation to the quantity of rupturing force, relatively exerted at this point, and others, and also an approximation to the quantity of masonry, and work to be done on the approaches.

The A. A′. line is the most southerly crossing investigated in detail. Below this the river is so much wider and the circumstances generally so much less favorable than those further up stream, that nothing in the way of measurements were made under my direction. The United States Coast Survey however accurately present the shore lines, and they have been transferred to the accompanying map. The connections by rail with the A. A′. line are spoken of elsewhere.

The next line in order of progression up the river, is marked B. B′.

Between A. A′. and B. B′., the River banks were run out by transit and the shore lines of the marsh and of Ionia Island, traced by compass and chain at the time the examinations were made last winter, for the information of the Legislature ; some of the measurements were made on the ice, but the greater part of the work was connected by triangulations, from bases, carefully measured on the track of the Hudson River Rail-road, which afforded excellent facilities for extreme accuracy. It is from these measures that this portion of the map is made up.

I find that it corresponds very nearly with the work of the United States Coast Survey, except in the position of the shore line of Ionia, which represents the river to be wider in some places, and narrower in others, by a few feet, then we make it.

I am particular, to call your attention to this discrepancy as the matter may be referred to in future, on account of the very high authority usually accredited to government work. But as our work was very carefully done, and under very favorable circumstances and proved its own accuracy by correctly closing upon our own bases I have assumed its reliability in the calculations, using our own data, and I think this may fairly be done, when the discrepancy is but little and where our work was *special*, and theirs only *general*; but it is of too much importance not to call your attention to the fact.

The section on B. B′. was never completed. Such examinations as were made, showed an unfavorable result when compared with other lines and as these conclusions are easily arrived at on the ground, without much analysis, it was deemed unwise to expend time, and money to no purpose.

The very favorable manner in which this location B. B′. can be approached from the westward by any line of railway induced me at first to consider it quite important, more particularly as a perpendicular crossing of the water-way of the river, from the shores of Ionia near this section, showed less distance then at any other place for many miles. In the table of comparisons, the value mathematically of this line is represented therefore only approximately, which must be borne in mind.

From the upper end of Ionia Island to Fort Clinton, and St. Anthony's Nose, our work corresponds very nearly with the coast survey. Our system of triangulations, and measurements, here were the same as below, which is an additional reason for presuming their accuracy, and they were proved again by careful chaining on the ice across the river at Fort Clinton.

From Fort Clinton to St. Anthony's Nose, we have several lines, varying in position from one another a few feet.

The section of calculation, and estimate is at C. C′. and this is the unit of comparison with all the other crossings.

Here plans have been made for a Bridge to carry broad, and narrow guage tracks for railway travel, and wagon roads, and foot passages.

Three systems of parapets have been considered, and all the

parts of the roadways, cables, anchorage, wind-guys, trusses, towers, foundations, anchor-pits, drains, tunnèls and other parts drawn to a scale, and the resistance, strain, compression and all other forces, together with the weights of the parts in equilibrium, suspended and on foundations, calculated and the cost estimated and tabulated.

Here the Bridge would have the following general dimensions.

Clear span, 1600 feet.

Distance between centres of towers, 1665 feet.

Total length of Bridge, including the anchors, 2499 feet.

Height of Bridge above the water 155 feet.

These dimensions now constitute a theoretical *Basis* of *Comparison*, between this line and all other locations. This however does not necessarily express any preference for the location, or otherwise, it is merely the method employed of making comparisons easily.

Next in order is the Fort Montgomery section, to St. Anthony's Nose. This line is marked D. D′. and here the span would be, as nearly as can be ascertained without making working drawings, sixteen hundred and fifty (1650) feet in the clear. This locality possesses a very great advantage of approaching the mountain on the east side of the river from the west side in the most favorable direction: far better than that from Fort Clinton.

The west bank, however, is comparatively low here, and the approaches would be long, and the masonry heavy: you will see by the table of the comparisons, how this difficulty is offset by the saving of excavation on the hill-side opposite.

Very many persons whose judgement is worthy of respect, consider this location far more desirable than the C. C′. line.

The approaches to all the sites being considered separately, but as a part of the whole problem, we pass on to the Section at the Consute Island.

It may be well to remark that at Fort Montgomery, a chain to obstruct the passage of the British fleet, was stretched out on a line very nearly corresponding to our vertical section on the line D. D′. and arguments are framed upon this fact, calculated to misslead those who do not thoroughly investigate.

It is claimed that the American general under the advice of the most able engineers of the time, selected this place for the obstruction of the river, because it is narrower than elsewhere and afforded the best anchorage for the chain.

The fact that the chain was put there, after careful consideration is not doubted, and that it was a very great acheivement for the times and circumstances under which it was done is readily admitted, but that the crossing is narrower here than elsewhere, is denied, not only does the United States Coast Survey, represent it more than two hundred feet wider than elsewhere, but our own triangulations and measurements, made on the ice last winter correspond.

Why, then, was the chain put here? we are asked. It was for these, among other reasons, that Forts Clinton, and Montgomery held the river from favorable positions, and were already built, that by placing the chain, where it was put, Fort Clinton could take the enemy in front at long ranges and in flank as they approached; and that Fort Montgomery could take them in flank, with their best guns, whereas if the west end of the chain had been swung to Pell's Point, Fort Montgomery would have reached the enemy from an oblique front only at the chain, or at long range as they approached it. If the chain had been put at Icnia or at Consute where the river is much narrower, the two forts would have borne upon the enemy in the first case at long range only in front, without the advantage of a flank fire, and in the other case at still longer range in the rear only.

If we push the inquiry further and ask why were not the forts built at points, where the river could be chained to the best advantage, I answer that the river was chained to the best advantage in a military point of view; the chain was an after thought, the forts had been built in the best position to command the river and the chain was put where the forts could best protect it.

There is no relation between the considerations that govern the construction of military offensive and defensive works, and such a structure for purely commercial purposes as you contemplate erecting, because, the place was more suitable for a fort,

and chevaux de frieze, it does not necessarily follow that it is best for a bridge.

The lines, and sections E. E'. at Consute or Marsh Island, next require attention.

From a point some three quarters of a mile above Fort Montgomery to the marsh, south and west of the Consute Island I have depended altogether on the U. S. Coast Survey. for the shore line of the river. The upper contours, for topography were made under my directions.

At the marsh, and Consute we have our own work again, to rely upon, and find it corresponds very nearly with the Coast Survey; we have however taken all the details, they have only the general facts.

The width of the river at the narrowest place is fourteen hundred and sixty-five feet, and a bridge may be made, having a clear span of fourteen hundred and eighty feet, and total central span between centres of towers of about fifteen hundred and ten feet.

This is with one exception, the narrowest place on the river within your assigned limits, and in fact within a range of one hundred miles or more, and that other place is at the north end of Grants Island, where the river may be some thirty [30] feet less in width, upon a point of rocks, utterly unsuited for our use on the westerly side, and on the east, the rocks are so steep and directly perpendicular to the axis, that without the expenditure of incredible sums of money, the crossing would be impracticable; besides, if this narrow Grants Island passage is used, it would require about two thousand feet of trestle work, one hundred and fifty-five feet high to approach it from the west.

The line E. E'. affords good facilities for anchorage on the east side at little expense, on the west they will be equally good, and safe, but will cost some more, and there is abundance of room on either side of the river, for all the approaches by rail, and highway.

The greatest draw-back to this crossing is the cost of the approach between the backstays on the westerly side.

Above Consute Island to Buttermilk Falls I have again

relied upon the U. S. Coast Survey for the shore lines represented on the map.

There is no desirable section upon which to cross within the distance; at least there are so many other places, so much more favorable elsewhere, that no effort has been made to do anything with what opportunities may be here presented.

It is proper to say though, that there are those who warmly advocate, a crossing near Cozzen's directly at the Falls; but in my opinion it is not worthy of consideration, where so many much more favorable points are to be found.

You, thus, have all there is within your assigned limits authorized by law, and the decision will in all probability be arrived at, in favor of one of the five sections indicated, or upon some slight modification of one of them.

You will see by the table of comparisons of strain that there is great disparity between the forces exerted at the different places.

The A. A′. line at Round Island shows the greatest strain upon the main cables, and by far the greatest quantity of masonry, and in fact the greatest of everything involving cost, while the facilities of bringing a rail-road line to it and from it, are equal to, if not superior to any other place, but there is no room on either side for anything like a town, or in fact, even depots or sidings without immense expenditures, as the lines are on the steep rocky side hills.

The line E2 shows the manner of approaching the A. A′ location from the west with a grade of sixty feet to the mile, and the line E3 shows the connection with the Erie and New England Railway, and the Hudson River Railroad on the easterly side.

At the point F about one half a mile from the dump of the Forest of Dean Iron mine Railway, near the house of Mr. Noah Brooks, there is the bottom of a natural pass in the hills, five hundred and twenty feet above tide, which is common to all lines, coming from the west to any site you may select for the crossing of the Hudson River. I wish to impress this fact distinctly upon your minds as very much depends upon it.

Now, to reach the A. A′. line from this place F. with a grade

of sixty feet to the mile, you must not only use all the distance there is directly on the side hill, but the line must be elongated by developement to F'. and back again to F''. and thence to the point A. this will bring the train in the right direction to cross the bridge with the engine in front: otherwise if a line were taken from F. to A. on the side hill, the grade would be, one hundred feet to the mile.

Returning again to the common point, F. to reach the C. C'. section, or any of the sections from Fort Clinton to St. Anthony's nose, we must develope the railway location to the westward of Highland lake to F'. and return to C.

This will bring the train coming from the west, so that the locomotive will be at the rear, when it reaches the bridge.

There are some advantages in this plan of crossing,as a special engine may be used by the Bridge Company, for taking all trains across, that come from any direction ; this would preclude the possibility of any collision upon the bridge, and has other advantages, such, as the care that would be taken by the engine driver, to run according to rules established by the Bridge Company, while if all Companies are allowed to take their own trains across in their own way, with their own engines and men, such rules cannot be so easily enforced.

Or, if it is thought best, a turn may be made at H. which will not augment the development, and will place the trains head on, to cross the Bridge in the usual way.

On the easterly side of the river, the connections with railroads to the south and east from the C. C'. line, must be made by a very heavy, and expensive cut in St. Anthony' Nose. If a directly descending grade from F. to Fort Clinton, is run by the shortest route F. C. it will be one hundred and ninety feet to the mile.

The connections to the north and east, are more readily made, but either a reverse V. must be adopted, or a tunnel on a curve to make the best combination practicable for leaving the bridge in both directions.

We must again return to the point F. and follow the line to F'. F''. there return to D. to reach the D. D'. line.

You will readily see the facility with which this Fort Montgomery and St. Anthony's Nose line leaves the side hill, on the east going to the south.

Those of you, who have seen the ground cannot fail to appreciate the importance of this fact.

The very great saving there is in the lines of approach on the east, on the C. C'. line, is too obvious to be overlooked, but we must not forget that to reach the connections of the Boston, Hartford, and Erie Railway near Fishkill if such a road is ever built, or to get to the Dutchess and Columbia Rail-road now being constructed, we must turn to the north.

This is not such an easy matter to do; in fact the work will be exceedingly heavy, and seems to be almost or quite impracticable, unless we continue the direction of movement after crossing the Bridge from the west, to the point I there put in a V, and reverse to the north on the line K: this will bring you into a tunnel at J. K. or a deep cut in the rock costing as much or more than an under-ground route.

From F. to D. by the most direct route the grade will be one hundred and ninety feet to the mile, hence the necessity for making the development to F'. if you require the gradients not to exceed sixty feet to the mile.

The line F. L. L'. L''. saves developing so far to the south as the Point F'. and this modification is applicable to the locations of the A. A': B. B': C. C': and D. D'. sections.

We will now for the fifth time return to the point F. and carry your eye along the blue line M. M'. M''. M'''. to E.

This shows the westerly approach to the crossing at the section E. E'. at Consute Island, including the necessary development, to obtain a grade of sixty feet to the mile. From F. to E. by the most direct line, the grade is ninety-one feet to the mile along the undeveloped line F, N, N', N'', E.

And now, allow me to make a statement that you doubtless may have anticipated. The developed lines of sixty feet grade to the mile from F. to A., F. to B., F. to C., F. to D., F. to E. are exactly the same length in feet and inches.

It, therefore follows, that as the point F. is on the location

from Turner's to the Hudson River, and is common to all the Bridge locations, that with sixty feet grades, *developed lines*, all the proposed Bridge Crossings are precisely the same distance from the Erie Railway, when they are made at an elevation of one hundred and fifty-five feet above tide, while if we follow the direct, and shortest route to the river, the most favorable grades upon an undeveloped line would take us to the E. E′. or Consute Island location.

The next best, so far as grades for rail-road approaches go, would be at the A. A′. line at Round Island. The next best is the B. B′. section at the upper end of Ionia.

The two least favorable in this respect and which if you have been enabled to keep your mind on this dry, but necessary subject, you will find to be at the C. C′: and D. D′. sections respectively at Forts Clinton and Montgomery, and so far as undeveloped lines affect the question of grades, they are alike and the worst there are.

At the general location at Consute Island the details on three sections have been worked up, one of these lines for purposes hereafter referred to, has been put at a higher elevation above tide.

The other is merely a modification of the E. E′. line to ascertain the best way of making the easterly towers.

The modified high line at this section is for the purpose of facilitating anchorage on the west side, this line is O. O′.

The examinations that have been thus far made on the ground, on this high line are not sufficient in detail to justify any conclusions, but if it is found best to adopt them, it will reduce the grades on the undeveloped line to eighty-eight feet to the mile, and shorten the length of the developed sixty feet to the mile line, thirteen hundred and twenty feet. So that with the modified crossing, the E. E′. section, would be a quarter of a mile nearer to Turner's, on the Erie R. R. than any other location: Now, I think, you will readily see as I see, by calculations, and on the ground that "the sum of the whole matter" resolves itself into a comparison between the C. C′. line, and the E. E′. line, as all the others have features well defined against them, which are not so prominent against these two.

Your charter contemplates the construction of a Bridge for the passage of railway trains as well as the travel of common highways; whether you can dispense with one, or the other, is a question for lawyers, or the courts to decide. I have supposed you are required to make the means for the public to cross in their own way with their teams, horses, cattle, and other property, if you make the Bridge at all, in this I may be mistaken, and there are very intelligent gentlemen, who hold another opinion, namely, that you can make the railroad Bridge, without providing for any other kind of travel.

If this is the correct view of the case, then you should surely consider it with reference to the kind of travel, you propose at the different localities. Supposing that you have the right to do as you please in this respect, you would save very greatly by not making a highway bridge, if you adopt the C. C'. line. At this section there are no public roads that come near the place, and to construct one along the face of the cliffs, south of St. Anthony's Nose, towards Peekskill, and to prepare a place for the connection of any Rail-road leading to the north from the Bridge is very expensive.

In fact, over 400,000 cubic yards of rock must be removed for this purpose, collectively, including what is necessary to make room for the anchorage.

It may be that the present route from Peekskill to Garrisons, can be tapped after it crosses the mountain, and in this way turn to the south from the old Deming Estate along the face of the hill.

This would perhaps save one hundred thousand dollars ($100-000.)

On the west side of the river, the cost would be much less, as merely an ordinary road, for say a mile, or less, would be required, with a Bridge over Popolopen Creek.

The great travelled road from the East, to the West, through this part of the country is from Lake Mahopac, to West Point via Garrison's.

At the Consute Island the Bridge, would be directly in the line of this travel, requiring not more than a quarter of a mile

of highway to be built altogether, to give all the facilities that could be required on both sides of the river.

Then again, at Consute Island, the anchorage on the west side will be more complicated, and costly then at Fort Clinton, exactly how much this will be, at either place cannot be known, until the rocks are uncovered, and tested.

There is an important feature at Consute not to be overlooked. The wide plains on either side afford the means of making all the depots, cattle yards, coal storage grounds, and every other facility of the kind, while at the C. C'. line, these facilities exist only at the Fort Clinton side.

The cost of the right of way at either of these two places, will be considerable if reckoned by the values, the owners, now put upon their lands, but as this is a question for a jury, if needs be, I have not investigated it very thoroughly. It will be, or I think it should be very nearly as much at one place as at the other.

So far as the interests of the Erie and New England R. R. Company, may enter into your calculations, it would be best for them to have the bridge at "Fort Clinton" because it will cost less for them to reach the Bridge than at Marsh Island. If however, you consider also a branch line to Fishkill, which certainly should come into the case, the railroads collectively, will not cost more from one site than from another.

The topography of the country is such, that whatever applies to the branch line from Fishkill, applies equally to the Dutchess and Columbia Railroad, or to the Boston, Hartford, and Erie, if it terminates at Fishkill. The wind coming from the north-west is recorded as the most severe that blows in this region. With reference to it, Consute Island is the best, for the Bridge will not be the only object in a concentrated focus.

At Fort Clinton, the Bridge would be, as it were, at the neck of a funnel. If you turn your thoughts for a moment to the topography of the Country, this fact will be apparent.

If you build it at the Marsh Island this difficulty will be avoided. The plain is wider here than elsewhere, although the river is narrower, and the wind will not be concentrated so much.

upon it. I do not consider this, however, as more than an incidental advantage in favor of the upper line, for ample provision can be made at either place for security against any wind.

So far I have not attempted in the question of location to involve the subject of any special form of structure, although it must be manifest to you, that there should be changes of importance, due to the place, and the kind of travel, particularly that advantage be taken of any favorable circumstances of ground, that each site may present. Some general facts, and considerations may be useful in refreshing your memories upon points, I have already had the honor to lay before the association, from which your Company sprang.

These are added to and modified inview of the more complete information, we now have on the subject, and the greater amount of details that have been collected.

OF THE SUSPENSION BRIDGE.

At first, it might appear to be almost impracticable to make so considerable a span, as that which is required to cross the Hudson River, at any point without the assistance of intermediate piers of any kind. But the experience of the world, has shown that the limit that can practically be attained is not even approached in your case.

It is true that the span required is greater than that of any railroad bridge yet constructed of one single opening, but nevertheless so certain are the data upon which the calculation of the strength of, and strain upon all the points is made, that we can with perfect exactness, and accuracy determine the conditions, that will govern the passage of every load upon the structure.

Let us look at a few of the simple elementary principles, that are involved.

In the position of the cable of the Suspension Bridge, the forces which tend to rupture it, are increased by the manner in which they act upon the curves.

Practically they are nearly double that which they would be, if they were sustained by the wire *endwise.*

If therefore a strand of wire, which would carry fifteen hundred pounds, less its own weight, say fourteen hundred, is strained when put into the position of the cable, with double its weight in consequence of the shape of the curve, it follows that there would be something over five hundred and fifty pounds, left for the strand to carry, besides its own weight.

Then, if in order to be perfectly safe, we say that the strand shall only carry one fifth ($\frac{1}{5}$) of what will break it, it follows that the wire will carry its own weight, and something over one hundred pounds besides, when it is in place in the cable. A very simple calculation determines how many strands are necessary to carry any given load; for if one strand in position will carry its own weight, and one hundred pounds, two strands will carry their own weight, and two hundred pounds, and so indefinitely, and we have merely to ascertain, what load can at any time come upon the Bridge, to determine the exact number of strands, that are necessary to carry with perfect safety, the very heaviest load.

If, however, on the other hand the span of the bridge is so great, that the wire will not sustain its own weight, for the necessary length, it becomes impracticable with our present materials to make the bridge of such a span.

In your case, the span required to cross the bridge, at any of the points within the Highlands, will not exceed one half of that which would be safe.

I shall not attempt to enter upon the discussion analytically of those questions, which involve the ultimate destruction of a work of this kind in equilibrium.

For your purpose now it will be sufficient to say, that in England, in France, in Germany, in Peru, and in China, these bridges have been in use for many, many years.

In all the calculations of the strength and strain of the Bridge, we have allowed for five times as much weight, as can be brought upon it, under any circumstances.

A train of locomotives of the heaviest kind, filling the bridge from one end to the other, and rushing over it at the rate of thirty miles to the hour, while the road-way is filled with a

crowd of people, as close as they can stand, which is the heaviest possible load, that can be brought under ordinary circumstances upon a common highway, would not strain the Bridge more than one sixth (1-6) of that which it is able to bear.

On either side of the River, the best possible advantages exist for anchorage in the granite rocks.—They are better however as before stated in some positions than in others.

The anchors are made in such a manner that not only all the force exerted upon them, is insufficient to rupture the rocks, but if a cone of stones of the size of the cone of rupture, was simply to be laid upon the anchorage, it would be enough to hold them in place.

That is to say, if the stones were simply piled up, instead of being natural rocks, in their original bed, their weight would be sufficient.

We, therefore, do not depend, for the stability of the structure upon the cohesion of the rocks themselves. This is a supplementary and additional advantage and could be dispensed, with, but in order to use every precaution, I have provided that all the interstices of the rocks, should be picked out clean, and where the seams are considerable, they are to be filled with hydraulic cement concrete ; where they are less, lead will be used, and where they are small, melted sulphur is to be poured in.

Thus not only the moisture will be kept out, which might otherwise corrode the anchors, and anchor chains, but the whole surrounding rock, will be made into a homogeneous mass. The anchor pits are also to be drained by tunnels below.

The main-stays, the cables, the guys, and the roadways, are at any temperature either the hottest weather of summer, or the coldest weather of winter, in perfect equilibrium, and the stability of the structure will depend not upon any truss, or upon any counter-brace or guys, but its own dead weight will keep it in place.

The object in making the bridge in this manner, is to prevent the possibility of any strain coming unduly upon any of the parts.

Where the whole Structure is in perfect equilibrium, nothing could be strained beyond its proper proportion.

If a truss should be used in connection with the cables, the ends of which are inserted in the solid rocks, the truss being in a straight line, while the cables were upon the curve, it necessarily follows, that where the truss and cables are connected together, where changes of temperature such as are usual in our climate take place, the truss will alternately have the whole weight to carry, and then nothing at all, while the cables on the other hand will alternately have the whole weight to carry, and then nothing at all.

In so large a Structure as this, it is necessary that each part should bear its own proportion of the load; hence the cables are made to carry the weight of the deck of the bridge, and any load upon it, and their own weight, and the parapets are merely used to distribute the load, along the cables.

Experience has shown that trusses, however desirable, they may be, when they are not connected with the catenary, are very ineffectual when they become part of the system having curved lines in it, especially when the curved lines are of metal and the truss of wood.

Timber of any kind does not expand or contract endwise by change of temperature, or by moisture, or but very little.

In fact, it matters not, how hydromalic the timber may be, its length endwise changes very little with change of temperature, or even saturation.

Iron, and steel are both very much affected by all classes of atmospheric phenomena; from the hottest weather of summer to the coldest of winter, we have a range of about one hundred and forty degrees Fahrenheit.

This upon a bar of good iron, will change its length about one part in twelve hundred; that is to say, if a bar of iron is twelve hundred feet long, in the coldest weather of winter, it will be about twelve hundred and one (1201) feet long in the hottest weather of summer.

It is therefore of the first importance that all the parts of the bridge, should be so arranged, that whatever changes of temperature, or moisture, or dryness takes place, either in the cables, or the suspension rods, the horizontal, or vertical guys,

or the deck parapets, they should all expand, or contract a like or if they do not, that they should change their length, due to atmospheric changes either of heat, cold, or moisture, in such a manner, as not to impair the strength of the structure in any way.

This cannot be done, where a perfectly rigid horizontal beam, resting on masonry at either end, is connected with the catenary or chain in the form of a parabola, which changes its length, with every change of temperature of the atmosphere.

You will readily see, how necessary it is that the chains should bear their proportion of the load, however, distributed when you realize, that under the most favorable circumstances, you may expect a change of at least a foot in the length of your main cables, between July and January. Now if the deck is made of wood and rests on the masonry at either end, it must be so flexible, and yet so stiff as to transmit its load, while the flexibility permits the cables to change their length and yet remain relatively to the load, on the Bridge, the same under all conditions.

OF THE CABLES.

Three plans for making the cables, have been estimated upon. The first is of steel plates or bars, twelve feet in length each. These bars are to lie edgewise. They are an inch and three quarters, (1¾ inches) thick, and nine inches wide.

Messrs Kruppe of Essin in Rhenish Prussia, have offered to make, and deliver them at the work, at thirteen and a half (13½) cents gold, duties paid.

Their agent here, a very intelligent gentleman, well versed in the manufacture of heavy steel shafts, and who is quite familiar with the subject, assures me, that they may be so bored in the eyes, as to be absolutely uniform, and suggests as a plan for doing this, that they should be so packed in a room for several days, in such manner that each plate will be absolutely of the same temperature when bored, and that thus they will all be the same length precisely, and each bear its own proportion of the weights.

In the construction of the Suspension Bridge over "Menai Straits," and at "Conway" and "Hammersmith Market Bridge over the Thames," difficulty was experienced in so boring the links of the chains, that the pressure was uniform upon the pintles.

Messrs Kruppe & Co. will undertake to remedy this difficulty, and their method is to bore all the plates under a uniform temperature.

I admit, that this to a very great extent relieves my mind of the anxiety that I have heretofore experienced in proposing this system of construction.

The very considerable saving in expense, is in favor of steel-bars or chains.

There is however, another difficulty in this case, and not a slight one, arising from the fact that in order to secure the greatest stability of the Bridge, we make the cables on the saddles, on the tops of the towers, farther apart than at the centre of the Bridge, and hence the cables have a horizontal as well as vertical curvature; now to conform to this curve, wires are much more easily adapted to the case, under uniform strains than bars, and pintles, because each series of links must be bored in the eye upon a line conforming to the horizontal curve,—which seems very difficult to do.

The doubt however has always been in my mind, that an uniform strain could not by any possible device, be assured in every part of the cable.

The very least difference in the length of one bar, by the side of another would throw the strain irregularly upon the pintles; the thickness of a sheet of paper would be enough to strain the printle unduly, or to give too much or too little to any link.

Hence I have advocated the use of wires laid in parallel strands, but if it is certain that steel can be used as proposed by these eminent manufacturers, it may be well to employ it.

We have not, however sufficient data upon this subject to come to an intelligent conclusion.

The strength of the Bridge depends of course upon the cables; if every part of the cable is not exactly right and does not bear

its due proportion of the load, some other part will be unequally and perhaps unduly strained.

The weight then comes on the next part, and gradually the whole bridge breaks away.

But if each part takes exactly its own load, and under all circumstances of change of weather maintains that load, and has nothing more to do, than its proper share, we should have no fear whatever of the structure lasting for centuries, if otherwise properly protected.

The second estimate is for wire.

It is proposed to make four systems of cables, five in each.

This will enable us to distribute the load so as to avoid any horizontal action from the wind, and prevent vertical waves: cables all being of the same length, they will expand, and contract alike, and whatever changes of grade line takes place in the roadway, will merely be a crowning to the bridge.

If we use wire, or steel bars, the load is the same on the bridge, with the exception of the weight of the material, itself.

I have estimated, that the Bridge shall be strong enough to carry a train of locomotives, across its entire length, moving at the rate of thirty miles to the hour, and having the roadway filled with passengers at the same time. Loading it equal to two hundred pounds to the square foot on the highways, and three tons to the foot on the roadways, and tracks, and six times this amount for the breaking strain.

THE EFFECTS OF WIND.

At the very considerable height of this Structure above tide, it is necessary to provide against the unusual currents of wind, as well as the regular breezes of the river.

For many years past, the Smithsonian Institute at Washington has carefully collected, and collated facts, which enable us to know, the exact pressure to the square foot of the ordinary gales, and of all the winds that blow upon the continent, even to tornadoes, that tear up trees, and blow down houses.

These vary from a few ounces to the square foot up to forty-nine pounds, when it is found that the wind moves at the rate of one hundred (100) miles per hour.

At page 457 Ordnance Manual published by the United States Government for the year 1861, the pressure of the wind is tabulated and we find the following general facts.

One mile an hour, pressure hardly perceptible; two or three miles an hour pressure just preceptible. Five miles an hour, gentle wind pressure one tenth (1-10) of a pound to the square foot. Fifteen miles an hour pressure one and one tenth (1.1-10) pounds to the foot, and the wind pleasantly brisk. Twenty-five miles to the hour, three pounds to the foot, and wind very brisk. Thirty-five miles, an hour, six pounds to the foot, high wind. Forty miles to the hour, seven and eighty-seven hundredths pounds to the square foot, and wind very high. Fifty miles to the hour, twelve and three tenths (12.3-10) pounds to the square foot, and storm, or tempest. Eighty miles to the hour, thirty-one and forty-nine hundredths (31.49-100) pounds, hurricane. One hundred miles to the hour, forty nine pounds, and hurricane that tears up trees, and carries away buildings.

This is recognized authority, and is probably as reliable as anything that exists in the world, upon the pressure and velocity of wind.

In the calculations for the strength of the Bridge, and the size of the various parts allowance has been made for the wind at the highest known velocity.

The plans show the method of sustaining the structure sidewise, and at all times against all currents, let them come in any direction that they may. Very considerable care is necessary in so arranging the parts, that if the wind, strikes the structure from beneath, from above, or obliquely upon the side, that none o the parts are unduly strained so as to cause rupture.

But all these forces are ascertainable quantities.

They can be calculated with the same certainty, and provision made to resist them, as easily as that of any other known force and this has all been provided for.

DURABILITY OF THE STRUCTURE.

You will agree with me that it is necessary that the bridge shall be strong enough to stand any load that may ever come

upon it, under any circumstances, or conditions; and that it shall resist the force of the wind, and be capable of sustaining itself against the weight of a train of cars or herd of cattle, or of as great a crowd of people as can get upon, and rush across.

And having made the bridge strong enough to do all this, let us see whether we have provided for its durability.

The destruction of any material, if it be of wood, or stone, or metal, depends upon circumstances that surrounds it.

The mountains of granite are gradually abraded, and the dé bris washed into the valleys.

The secondary formations of rock, are more readily acted up. on by the elements.

Metals of all kinds, corrode more, or less. Wood changes its structure by excessive heat, cold, or continuous moisture, and all material is more or less perishable.

But that which is designated in our language as destruction, arises from chemical changes, or mechanical force: these changes are governed by well-known laws.

For instance if a bar of iron, subject to the action of moisture and the atmosphere is said to rust, we have simply in this case, the absorption of oxygen, and the giving off of hydrogen.

The scale is an oxyd of iron. It is a union of the elements, of the watery parts of the atmosphere, with a certain number of the particles of the iron.

Now, when the iron has taken up all the oxygen that it is ca. pable of holding, it will take no more.

If the bridge is already rusted artificially, or covered with a sufficient covering composed of rust, so long as this remains in it, it can rust no more, if the coating is thick enough to keep out the external air and moisture.

In order to apply this practically, it is proposed, if strands of wire are used, to mix the ground ore of Franklinite, which is a natural rust, with something to form a covering and to coat each strand.

It is iron united with oxygen. It is the same thing as the rusty scale of iron would be, if formed in the natural way, but containing zinc, and other desirable metals.

A paint of this kind is to be found in use in the Niagara Suspension Bridge at Lewiston, and the St John Bridge over the falls of St. John, which has lasted for thirteen years without alteration; and it may safely be predicted, that if the cables are painted properly from time to time, they will last a thousand years.

OF THE MASONRY.

You will see by the plans, that a very large amount of masonry will be necessary.

Most of this must be first class.

In order to secure perfect stability to the towers, it is proposed that they shall stand upon independent masses of masonry, resting on the natural rock.

This rock as has been before stated is the primary formation of columna granite. The retaining walls about the approaches need not be of such costly work.

The towers are to have cut joints, and builds, and the whole is to be laid in hydraulic cement. The upper courses must be doweled, and bolted together, and it will probably be found best to do this with copper rods passing through at least two or three courses.

In the estimates I have divided the masonry into three classes; first the foundations; second the retaining walls, and third the towers.—These are again subdivided according to the kind of face, they are to have, rock faced, scabble work, hammer dressed &c.—The Anchor masonry is distinct of itself.

The tops of the towers will be fine cut, the rest of the towers is rock faced with aris lines in the joints.

THE SADDLES.

In order to provide for the change of length, that will take place by the expansion, and contraction of the back-stays, or that portion of the cables, which is between the anchors, and tops of the towers, a system of horizontal, steel rollers is to be inserted, between two plates of cast iron.

The lower one of which will rest upon a lead-plate on the top of the masonry of the towers.

The upper one is above the steel cylinders, and is called a saddle, the top of which will be the segment of a circle, terminating in tangent lines.

If no provision were made for a motion upon the tops of the towers, the lines of force, would be thrown off the vertical axis of the tower, the tendency of which would be to upset the masonry and tear it apart.

The cylinders referred to, between the plates of cast iron, with steel faces, will prevent any action of this kind.

Just enough to compensate for the expansion, or contraction of the back-stays so that in all cases, the forces will be vertical upon the tower.

It has been necessary in some bridges to make towers inclined, where there was not room to extend the back-stays a sufficient distance to the rear.

You have no difficulty however, of this kind in your locations; the towers will be plumb, and all the forces, resulting from the load on the Bridge, the weight of the Bridge, itself, and anything that may be upon it, will be directly vertical, and through their axes.

All the masonry of the foundations and towers must be so laid, that the stones will receive the force, perpendicular to their natural beds.

The weight on the stones, tending to crush them, has been put at very much less than they will sustain, the object being to make a large mass of masonry to resist vibrations.

A new system of taking up the slack of the horizontal wind guys, has been contrived which is very simple, and will doubtless be found effectual; it is shown in the drawings.

On the whole, you may rely on the foundations, upon the strength of the Bridge, and its durability as being all that can be reasonably desired.

It is fortunate for us that scientific inquiry has settled beyond question, everything that we have to deal with, in building a bridge so far as *forces* are concerned.

All such problems as the direction, and quantity of force exerted at any point, and the nature of this force, together with the ability of given materials to resist any forces either of twisting, with which we have but little to do, or with compression, or extension; all these are well defined beyond dispute, by the rules for determining the composition and resolution.

If we were compelled to enter the field of speculative philosophy, to inquire into the correlation, or the conservation of forces, Doctors may be found who differ.

With these differences we have nothing whatever to do in building a bridge, however desirable they may be to investigate for other purposes.

I had prepared some general remarks upon the methods to be employed, to determine the best kind of materials for use, such as stones, cement, wood, iron, and steel, together with inquiries into the nature of these materials, and their manufacture, and analysis, but as the paper has already grown into perhaps undue proportions, and as all such matters would apply equally to any location, you may select, and to all similar cases, I shall hope to present them for your consideration, when you have determined the general location, and settled whether you will have a single or double track bridge, and whether you will include public highways as well as Railways, or not, and what maximum gradients you will permit for the approaches.

The following is a table of the Ratios' of Strains, and quantities at the five selected localities; the section at C. C'. being unity.

These are easily counted into prices and cost, when you determine upon any locality.

1st. Shall there be highways?

2nd. Shall there be a double, or single line of railway?

3rd. The maximum grade of the approaches.

TABLE.

	Fort Clinton C. C.′	Round Island Two Spans, A. A.′	Grant's Island, B. B.′	Ft. Montgomery, D. D.′	Marsh Island, E. E.′	Marsh Island, O. O.′	REMARKS.
Clear Span......	1600	1950	1600	1650	1480	1570	
Length of Cable.	2632	5172	2632	2772	2411	2540	Above Deck.
Strains on Cable.	29158	40858	29158	30025	25168	27471	
Land Spans	0000	1100	3200	200	2100	2000	
Total length of Structure.....	2499	5260	4800	2450	3580	3570	
Masonry........	59311	208068	114372	62356	90700	90700	Towers and Piers.
Approaches.....	800.000	40.000	800.000	800.000	10.000	70.000	Earth and Rock Work.
Anchorage	488.368	673.480	1.173.844	505.110	1.466.078	1.531.497	Including Cable below Deck.
Cost Ratio.......	5.680	14.024	7.335	6.150	5.510	5.778	

As very much has been said, in the vicinity of the work, about the practicability of a railway connection from the E. E'. location to Peekskill, crossing the mountains east of St Anthony's Nose, through the pass, now used by the Peekskill, and Garrison's highway, I have run an aneroid line over it, and find it to be impracticable with sixty feet grades, without making a tunnel, I should judge a mile long.

The pass is about four hundred and twenty-five feet above tide, and the grades without a tunnel would be about one hundred and thirty feet to the mile.

In order to preclude the possibility of any doubt, in regard to the eagle valley pass, west of West Point, I ran a barometrical line of levels, and found the gap at the head of Buttermilk Brook to be over eight hundred, and twenty feet above high tide. These were mere precautionary measures, and add to your certain knowledge of the ground, important data.

You will, I believe, see by these investigations, that all the railway interest so far as connecting with the bridge is concerned, have been considered.—The Hudson River Rail Road can form connections, the West Shore the same, the Midland can come upon it, the Boston, Hartford, and Erie, and the Dutchess, and Columbia by the line of the Erie, and New England, and the Fishkill Branch, and in fact all existing or contemplated lines, can be accomodated.

Trusting that these facts, here presented will give you such information as you require, I have the honor to be very respect fully,

Your Obedient Servant,

EDWARD W. SERRELL,

Engineer in Chief.

Printed by order of the Board for the use of the members.

JAMES H. JENKINS,

Secretary.